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RTCA Special Committee 186, Working Group 5

ADS-B UAT MOPS

Meeting #7

Brussels, Belgium

DRAFT 3 of Section 2.2.4 of the UAT MOPS

(by James Maynard, but
presented by Chris Moody)

SUMMARY
The following represents a third draft of Section 2.2.4. This draft is based on the second draft, UAT-WP-4-07, with additional text added to describe some of the ADS-B message payloads in more detail. In this draft, I attempted to provide space in the ADS-B message formats for a variety of new MS and OC report elements that are being proposed for inclusion in the DO-242A revision of the ADS-B MASPS. Mostly these are annotated with "Commentaries" that are to be removed in the final version of the MASPS.

Author's Comments

Provision is included in the Basic ADS-B Message format for the new NIC and NAC fields that would replace the present NUC_P field. The NUC_P field is annotated with a commentary that it would become the NIC field, and the NAC_P field is called "reserved for NAC_P". These are placed in the 18-byte Basic ADS-B format, as they indicate the quality of the position SV elements. That is, changes in the quality of the position data, especially changes that degrade that quality, would have to be communicated promptly, so they are included in the Basic ADS-B Message format.
The proposed SIL (Surveillance Integrity Level) parameter is placed in the second half of some of the Long ADS-B message formats, as it is expected to change only infrequently.
The Turn Indicator (TI) field is proposed to be eliminated from the MASPS. So I've indicated in a commentary that it might be replaced with a 2-bit Barometric Altitude Quality field. Details of the indication of barometric altitude integrity and accuracy still need to be worked out in WG-6.
The first two Long ADS-B Message payload formats (Long Type 1 and Long Type 2) include those Mode-Status report elements that are not already sent in the Basic ADS-B Message format: • Participant Category, Flight ID (Call Sign), • The proposed Surveillance Integrity Level (SIL) code, • Capability Class (CC) codes, • Operational Mode (OM) codes, • Emergency/Priority Status codes, and • MOPS Version Number. Both of these formats also include the Secondary Altitude. The primary altitude (typically barometric pressure altitude) would continue to be broadcast in the Basic ADS-B Message format, while the secondary altitude (typically geometric altitude) would be included only in the Long Type 1 and Long Type 2 Message formats. A proposed change to the MASPS would require only one of the two altitude rates to be broadcast , so "primary altitude rate" is conveyed in the Basic ADS-B Message format. We might want to find a place for secondary altitude rate, but if the MASPS is revised in the way the WG-6 is currently intending, transmitting secondary altitude rate would not be required.
The Long Type 1 and Long Type 2 Message formats differ in their last few bytes. In the Long Type 1 format, these bytes hold the elements of the proposed new OC-ARV (On Condition – Air-Referenced Velocity) message. In the Long Type 2 format, the same bytes would hold the elements of some other kind of On-Condition report.
TCP information would be conveyed in a Long Type 3 Message. This message format includes provision for future elaboration of the various flavours of TCPS, and for having more than just two TCPs (TCP and TCP+1). Other than defining the general structure, however, the only TCP Type defined at this point is TCP Type 0, which contains only those TCP elements that were defined in the initial version of the ADS-B MASPS. Space is provided for up to 4 different TCP types, and an undefined number of "subtypes" for each TCP type. This is because the MASPS is eventually expected to change to include more elaborate TCP types, with even more parameters, all of which is yet to be defined. The intent here is to have a structure which allows for growth.
Some of the new TCP elements being proposed might make it desirable to use fewer bits for TCP Latitude and TCP Longitude than I have proposed in the draft Type 0 TCP format. Probably it would be good to use the same number of bits for Latitude and Longitude an all the TCP message formats. I just don't know what that number of bits would be, so I have for the time being allocated a full 24 bits each, which I know to be excessive.
I don't presently have a place for the "short term intent" information: Selected Altitude and Selected Heading or Track Angle.

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2.2.4 The ADS-B Message Payload

There are several message formats used in the ADS-B part of the one-second frame. Table 2.2.4 summarizes these formats, which are distinguished by their Payload Type Codes (section 2.2.4.1.1).

Table 2.2.4: ADS-B Message Payload Types.

Message Type	Payload Type Code	Message Length	Message Contents
Basic ADS-B Message	0	Short	SV elements, some MS elements
Long Type 1 ADS-B Message	1	Long	Basic ADS-B content, plus remaining MS elements, and OC-ARV (Air Referenced Velocity) report elements.
Long Type 2 ADS-B Message	2	Long	Basic ADS-B content, plus remaining MS elements, and elements of another OC report (to be specified)
Long Type 3 ADS-B Message	3	Long	Basic ADS-B content, plus elements of OC-TCP, OC-TCP+1 reports, as they were originally defined in original DO-242 MASPS.
Long Type 4 ADS-B Message	4	Long	Reserved for basic ADS-B content, plus for elements of future, more elaborate, TCP, TCP+1, TCP+2, TCP+3, etc. reports.
Other ADS-B Messages	5 – 11	Long	Reserved for basic ADS-B content, plus elements of other OC reports.
(Reserved)	12 -- 15	Long	Reserved for other messages, that need not include basic ADS-B data content.

2.2.4.1 Basic ADS-B Message Format and Encoding

This subsection establishes the format and encoding of the Basic ADS-B Message Payload. Table 2.2.4.1-A shows the overall format of the payload, while Table 2.2.4.1-B lists the fields of the payload and the subsections where those fields are described.. Bytes and bits are transmitted in “big-endian” order; that is, the most significant byte, byte #1, is transmitted first, and within each byte, the most significant bit, bit #1, is transmitted first.

Table 2.2.4.1-A. Format of Basic ADS-B Message Payload.

Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
1	(MSB)	**Payload Type Code**		(LSB)	(MSB)	**Address Qualifier**		(LSB)
2	A1	A2	A3	. . .				
3				**Aircraft Address**				
4					. . .	A22	A23	A24
5	(MSB)							
6				**Latitude (WGS-84)**				
7							(LSB)	(MSB)
8								
9				**Longitude (WGS-84)**				
10							(LSB)	**P Valid**
11	(MSB)	**NUC_P *(or NIC)***		(LSB)	(MSB)	***(Res. for NAC_P)***		(LSB)
12	**TI *(or BAQ)***		**Air/Ground State**		**V Valid**	(MSB)		
13				**North Velocity or Ground Speed**				(LSB)
14	(MSB)			**East Velocity or Heading**				
15			(LSB)	**Alt. Type**	(MSB)			
16				**Primary Altitude**				(LSB)
17	(MSB)			**Primary Altitude Rate**				
18		(LSB)	(MSB)	**NUC_R *(or NAC_V)***		(LSB)	**T Valid**	(Res.)

Table 2.2.4.1-B. Basic ADS-B Message Payload Fields.

Field Name	# of Bits	Section Reference
Payload Type Code	4	2.2.4.1.1
Address Qualifier	4	2.2.4.1.2
Aircraft Address	14	2.2.4.1.3
Latitude	23	2.2.4.1.4.2
Longitude	24	2.2.4.1.4.3
Position Valid	1	2.2.4.1.5
NUC_P [or NIC]	4	2.2.4.1.6
[Reserved for NAC_P]	4	2.2.4.1.7
Turn Indicator [or Barometric Altitude Quality]	2	2.2.4.1.8
Air/Ground State	2	2.2.4.1.9
Velocity Valid	1	2.2.4.1.10
North Velocity or Ground Speed	11	2.2.4.1.11
East Velocity or Heading	11	2.2.4.1.12
Primary Altitude Type	1	2.2.4.1.13
Primary Altitude	12	2.2.4.1.14
Primary Altitude Rate	10	2.2.4.1.15
NUC_R [NAC_V]	4	2.2.4.1.16
T Valid	1	2.2.4.1.17
[Reserved]	1	2.2.4.1.18

2.2.4.1.1 Payload Type Code

The payload type code (byte #1, bits 1-4) indicates whether the AD-B message is a basic ADS-B message (18-byte payload) or a long message (34-byte-payload). In the case of a long message, the payload type indicates what type of long message.

Table 2.2.4.1.1. Payload Type Codes.

Payload Type Code	Message Type
0	Basic ADS-B Message
1	Long Type 1 ADS-B Message
2	Long Type 2 ADS-B Message
3	Long Type 3 ADS-B Message
4	Long Type 4 ADS-B Message
4-11	Reserved for other long ADS-B message types
12-15	Reserved for other uses

Payload types 0 to 11 are reserved for ADS-B messages. Message type 0 indicates the basic ADS-B message payload of 18 bytes carrying basic ADS-B SV (State Vector) information. Message types 1 through 11 indicate longer ADS-B messages, in which the first 18 bytes have the same structure as message type 0, carrying SV information. In these message types, bytes 19 through 34 contain other ADS-B information in addition to the basic SV information.

Message types 12 to 15 are reserved for future definition. There is no assurance that messages of these types will carry ADS-B information in their first 18 bytes.

2.2.4.1.2 Address Qualifier

The Address Qualifier is a 4-bit field that indicates the type of address being communicated in the Aircraft Address field. The various Address Qualifier values are defined in Table 2.2.4.1.2 below.

Table 2.2.4.1.2. Address Qualifier Codes.

Address Qualifier	Address Type	Reference Section
0	Own-ship ICAO 24-bit aircraft address	2.2.4.1.3.1
1	Own-ship self-assigned temporary address	2.2.4.1.3.2
2	ICAO 24-bit aircraft address of TIS-B target.	2.2.4.1.3.3
3	TIS-B track file identifier for TIS-B target	2.2.4.1.3.4
4	Surface Vehicle	2.2.4.1.3.5
5	Fixed ADS-B Beacon (“parrot”)	2.2.4.1.3.6
6-15	(Reserved)	

2.2.4.1.3 Aircraft Address

The meaning of the Aircraft Address field depends on the value of the AQ (Address Qualifier) field (section 2.2.4.1.2).

2.2.4.1.3.1 Permanent ICAO 24-bit Aircraft Address of Transmitting Aircraft

An Address Qualifier value of AQ=0 shall indicate that message is an ADS-B message from an aircraft, and that the Aircraft Address field holds the permanent ICAO 24-bit address that has been assigned to that particular aircraft.

Note: *The world-wide scheme for allocating and assigning the 24-bit ICAO aircraft addresses is described in Annex 10 to the Convention on International Civil Aviation, Volume III, Chapter 9. [ICAO Annex 10, Vol. III, Ch. 9]*

2.2.4.1.3.2 Self-Assigned Temporary Address of Transmitting A/V

An Address Qualifier value of AQ=1 shall indicate that the message is an ADS-B message from an aircraft or surface vehicle, and that the Aircraft Address field holds the transmitting A/V's self-assigned own-ship temporary address.

The self-assigned temporary address shall be generated as follows.

Let $ADDR_P$ = the permanent 24-bit ICAO address that has been assigned to the aircraft (if it is an aircraft);

$ADDR_T$ = the temporary address that is to be self-assigned;

M(1) = the 12 least significant bits (LSBs) of the own-ship latitude in 24-bit angular weighted binary notation at the time of startup or of the change of state of the Address Option input to "temporary";

M(2) = the 12 LSBs of the own-ship longitude in 24-bit angular weighted binary notation at the time of startup or of the change of state of the Address Option input to "temporary;

M(3) = $4096 \times M(1) + M(2)$; and

TIME = the number of seconds that have elapsed since UTC midnight at the time of startup of change of state of the Address Option to "temporary."

Also, let "⊕" denote the modulo 2 bit-by-bit addition (or "exclusive OR") operation.

If the transmitting ADS-B participant is an aircraft, and that aircraft's permanent 24-bit permanent ICAO address $ADDR_P$ is available, then the temporary address $ADDR_T$ shall be the modulo 2, bit-by-bit summation of the permanent address and M(3), that is:

$$ADDR_T = ADDR_P \oplus M(3).$$

If the aircraft's 24-bit ICAO address $ADDR_P$ is <u>not</u> available, or if the transmitting ADS-B participant is not an aircraft, then time of day shall be used as the additional randomizer. In that case, , the temporary address $ADDR_T$ shall be the modulo 2, bit-by-bit summation of TIME and M(3), that is,

$$ADDR_T = TIME \oplus M(3).$$

2.2.4.1.3.3 ICAO 24-bit Aircraft Address of TIS-B Target Aircraft

An Address Qualifier value of AQ=2 shall indicate that the message is a TIS-B message and the Aircraft Address field holds the ICAO 24-bit address that has been assigned to the target aircraft being described in the message.

Note: *The world-wide scheme for allocating and assigning the 24-bit ICAO aircraft addresses is described in Annex 10 to the Convention on International Civil Aviation, Volume III, Chapter 9. [ICAO Annex 10, Vol. III, Ch. 9]*

2.2.4.1.3.4 TIS-B Track File Identifier

An Address Qualifier value of AQ=3 shall indicate that the message is a TIS-B message and that the Aircraft Address field holds a TIS-B track file identifier by which the TIS-B data source identifies the target aircraft being described in the message.

Note: *It is beyond the scope of this MOPS to specify the method by which a TIS-B service provider would assign track file identifiers for those TIS-B targets for which the ICAO 24-bit address is unknown.*

Commentary:

One possible method for assigning such TIS-B track file identifiers would be to use:

- *The most significant bits of 24-bit Aircraft Address field to identify the TIS-B service provider (the source of the TIS track file),*
- *The 12 next most significant bits of the Aircraft Address field to convey the Mode A identify code by which the target aircraft has identified itself, and*
- *The remaining, least significant, bits of the Aircraft Address field as a serial number to distinguish one track file from another.*

2.2.4.1.3.5 Surface Vehicle Address

An Address Qualifier value of AQ=4 shall indicate that the Aircraft Address field holds the address assigned to a surface vehicle authorized to operate in the airport's surface movement area. To avoid duplication of surface vehicle addresses between vehicles at airports within a few hundred miles of each other, the scheme shown in Table 2.2.4.1.3.5 is recommended for the assignment of Surface Vehicle addresses.

Commentary:

> *The following text is in italics to indicate that it does not impose requirements, but only a suggested scheme for assigning permanent surface vehicle addresses.*

Table 2.2.4.1.3.5. Suggested Surface Vehicle Address Assignment.

16 Most Significant Bits *(Bytes #2 and #3, bits #1 to #8)*	***8 Least Significant Bits*** *(Byte #4, bits #1 to #8)*
*Three-Character **Airport ID*** *(Base-40 Encoding)*	***Vehicle Address** At That Airport* *(Binary Encoding, Range 0-255)*

In Table 2.2.4.1.3.5, the 3-character Airport ID should be the least significant three characters of the four-character ICAO identifier for the airport at which the surface vehicle is located.

Note: *For example, the airport at Salem, Oregon, USA ("KSLE") would be represented by "SLE."*

The same base-40 encoding should be used for the Airport ID as is described in Section 2.2.4.2.1.2 below for encoding the aircraft call sign. That is, the 16-bit Airport ID subfield would be the binary representation of the base-40 numeral,

$$A_1 ´ 40^2 + A_2 ´ 40^1 + A_2 ´ 40^0$$

In this formula, A_1, A_2, and A_3 are the base-40 representations of the three least-significant characters of the four-character Airport ID, according to the encoding shown in Table 2.2.4.2.1.2.

Note: *For example, for the airport at Salem, Oregon,*

> *A_1 = base-40 digit "S" = decimal 28,*
> *A_2 = base-40 digit "L" = decimal 21, and*
> *A_3 = base-40 digit "E" = decimal 14,*
>
> *so that*
>
> $A_1 ´ 40^2 + A_2 ´ 40^1 + A_2 ´ 40^0$
> $= 28 ´ 1600 + 21 ´ 40 + 14 ´ 1$
> *= decimal 45 654*
> *= binary 1011 0010 0101 0110*

The 8 least significant bits of the surface vehicle address should be an 8-bit binary numeral to identify a particular surface vehicle at the airport.

2.2.4.1.3.6 Fixed ADS-B Beacon Address

An Address Qualifier value of AQ=5 shall indicate that the Aircraft Address field holds the address assigned to a fixed ADS-B beacon or “parrot.”

Note: It is beyond the scope of this MOPS to specify the method by which ADS-B beacon addresses are assigned.

2.2.4.1.4 Latitude and Longitude

2.2.4.1.4.1 Angular Weighted Binary Encoding Method

Table 2.2.4.1.4.1 describes0 (and Figure 2.2.4.1.4.1 illustrates) the 24-bit angular weighted binary encoding that is used for the latitude and longitude of the aircraft that is transmitting the Basic ADS-B Message.

Note: The most significant bit (MSB) of the angular weighted binary latitude is omitted from the message. This is because all valid latitudes, excepting only the latitude of the N pole (exactly 90 degrees North), have the same value in their 2 most significant bits.

Table 2.2.4.1.4.1: Angular Weighted Binary Encoding of Latitude and Longitude.

Quadrant	Latitude or Longitude bits (MSB … LSB)	Meaning $INCR = Lsb = \frac{360}{2^{24}} = 0.00002146°$ — Latitude	Longitude
1st quadrant	0000 0000 0000 0000 0000 0000	ZERO degrees (Equator)	ZERO degrees (Prime Meridian)
	0000 0000 0000 0000 0000 0001	*INCR* degrees North	*INCR* degrees East
	…	…	…
	0011 1111 1111 1111 1111 1111	(90-*INCR*) degrees North	(90-*INCR*) degrees East
2nd quadrant	0100 0000 0000 0000 0000 0000	90 degrees (North Pole)	90 degrees East
	0100 0000 0000 0000 0000 0001	<Illegal Values>	(90+*INCR*) degrees East
	…	<Illegal Values>	…
	0111 1111 1111 1111 1111 1111	<Illegal Value>	(180-*INCR*) degrees East
3rd quadrant	1000 0000 0000 0000 0000 0000	<Illegal Value>	180 degrees East or West
	1000 0000 0000 0000 0000 0001	<Illegal Value>	(180-*INCR*) degrees West
	…	<Illegal Values>	…
	1011 1111 1111 1111 1111 1111	<Illegal Values>	(90-INCR) degrees West
4th quadrant	1100 0000 0000 0000 0000 0000	-90 degrees (South Pole)	90 degrees West
	1100 0000 0000 0000 0000 0001	(90-*INCR*) degrees Sourth	(90-*INCR*) degrees West
	…	…	…
	1111 1111 1111 1111 1111 1111	*INCR* degrees South	*INCR* degrees West

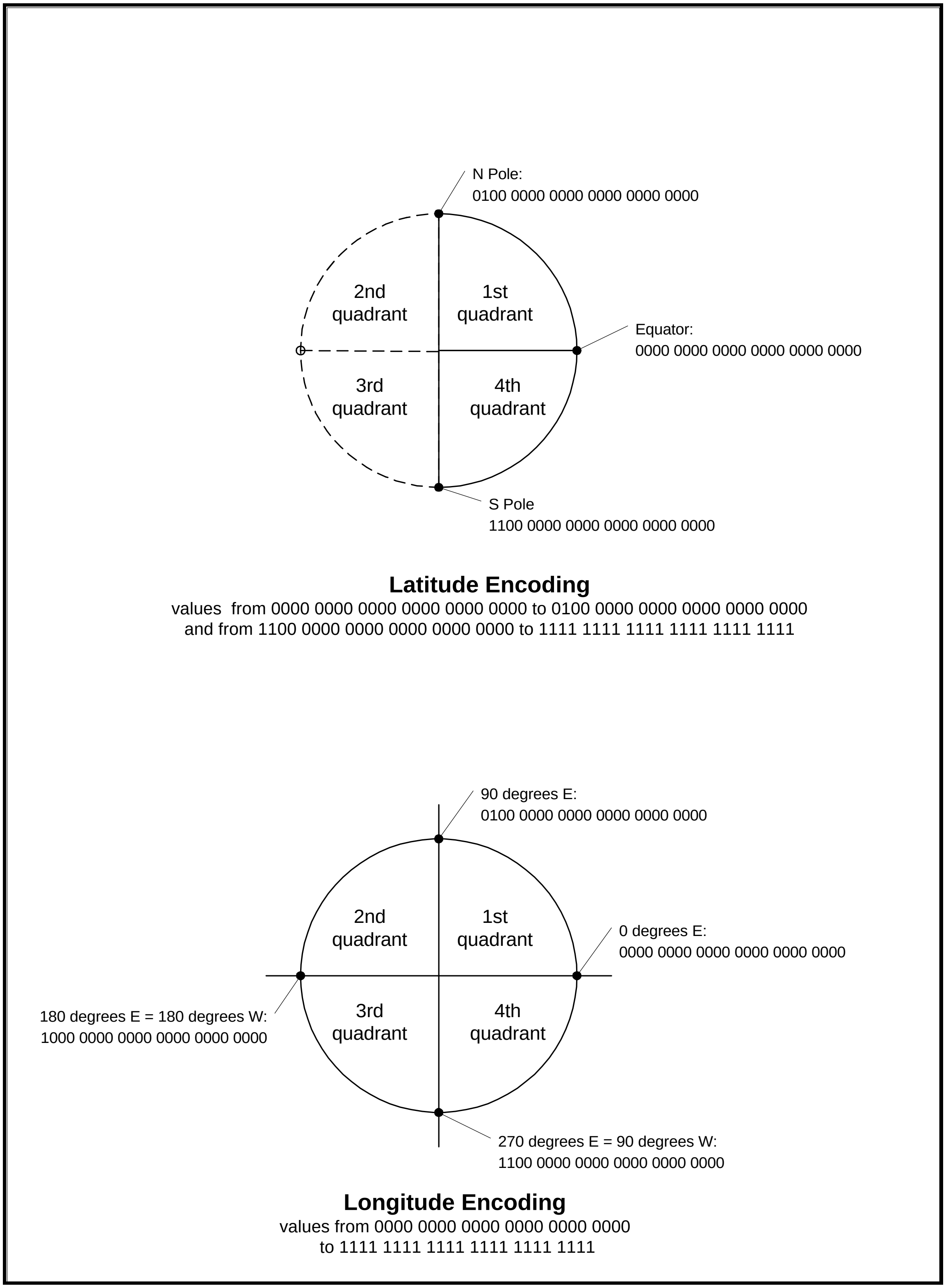

Figure 2.2.4.1.4.1: Angular Weighted Binary Encoding of Latitude and Longitude.

2.2.4.1.4.2 Latitude

The Latitude field is a 23-bit field (byte #5, bit #1 through byte #7, bit #7) that holds the aircraft/vehicle's WGS-84 latitude to a resolution of 2^{-24} circles (approximately 2.4 metres). It is formed by omitting the MSB from the 24-bit angular weighted binary numeral that represents the aircraft's latitude.

Note 1: *For latitudes in the range [-90°, +90°), that is, from the S Pole almost to the N Pole, the 2 most-significant bits of the angular weighted binary numeral representing those latitudes will be identical. That is why the MSB may be omitted.*

Note 2: *When the 23-bit Latitude field is decoded in an ADS-B receiver, the report assembly function should reconstruct the full 24-bit angular weighted binary latitude from the 23-bit field in the message. This will involve some minimal tracking function, so that the North pole (angular weighted binary 0100 0000 0000 0000 0000 0000) is not mistaken for the South pole (angular weighted binary 1100 0000 0000 0000 0000 0000).*

Commentary

In its 5th meeting, 2001 May 1-4 at Salem, WG-5 agreed to code the latitude, as shown above. However, the working group reserved the possibility, if more bits should be required for other fields in the basic ADS-B message, of moving the most significant latitude bits to the second half of one or more of the long ADS-B message types.

2.2.4.1.4.3 Longitude

The Longitude field is a 24-bit field (byte #7, bit #8 through byte #10, bit #7) that holds the aircraft/vehicle's WGS-84 longitude expressed in 24-bit angular weighted binary notation.

2.2.4.1.5 Position Valid (P Valid) Flag

The Position Valid flag is a 1-bit field (byte #10, bit #8) indicating the validity of horizontal position given in the Latitude and Longitude fields. This bit shall be 1 if the position is valid, or 0 if the position is invalid. If the "P Valid" flag is 0, a receiving device should assume that the Latitude and Longitude fields do not contain meaningful horizontal position information.

2.2.4.1.6 NUC_P (or NIC)

The NUC_P (Navigation Uncertainty Category for position is a 4-bit field (byte #11, bits 1-4) describing the integrity radius associated with the horizontal position information conveyed in the Latitude and Longitude fields. The various NUC_P codes are defined in RTCA DO-242, section 2.1.2.2.4.1 and reproduced in Table 2.2.4.1.6 below.

<u>Note 1</u>: *For NUC_P codes* 1 *7, the selection of the NUC_P code is determined by the value of HPL (Horizontal Protection Limit) indicated in the second column of Table 2.2.4.1.6. HPL is a containment radius that is one of the standard outputs of GPS receivers. HPL is defined as the radius of a circle in the horizontal plane, centered on the reported position, such that the probability is very low that the true position lies outside that circle without the possibility of its lying outside the circle being detected by the GPS receiver.*

<u>Note 2</u>: *For NUC_P codes 8 and 9, the selection of the NUC_P code is to be determined by the 95% accuracy bounds on the horizontal and vertical position from the third and fourth columns of Table 2.2.4.1.6.*

Table 2.2.4.1.6. NUC_P Codes.

<table>
<tr><th rowspan="2">NUC_P</th><th rowspan="2">HPL</th><th colspan="2">95% Accuracy Limits</th><th rowspan="2">Comment</th></tr>
<tr><th>Horizontal</th><th>Vertical</th></tr>
<tr><td>0</td><td>No Integrity</td><td>Unknown</td><td>Unknown</td><td>No Integrity</td></tr>
<tr><td>1</td><td>20 nmi</td><td>N/A</td><td rowspan="7">(Use Pressure Altitude.)</td><td>RNP-10 containment radius</td></tr>
<tr><td>2</td><td>10 nmi</td><td>N/A</td><td>RNP-5 containment radius</td></tr>
<tr><td>3</td><td>2 nmi</td><td>N/A</td><td>RNP-1 containment radius</td></tr>
<tr><td>4</td><td>1 nmi</td><td>N/A</td><td>RNP-0.5 containment radius</td></tr>
<tr><td>5</td><td>0.5 nmi</td><td>N/A</td><td>e.g., DME-DME</td></tr>
<tr><td>6</td><td>0.2 nmi</td><td>N/A</td><td>e.g., GPS-SPS (SA on)</td></tr>
<tr><td>7</td><td>0.1 nmi</td><td>N/A</td><td>e.g., GPS (SA off)</td></tr>
<tr><td>8</td><td>N/A</td><td>10 m</td><td>15 m</td><td>e.g., WAAS</td></tr>
<tr><td>9</td><td>N/A</td><td>3 m</td><td>4 m</td><td>e.g., LAAS</td></tr>
<tr><td>10-11</td><td>TBD</td><td></td><td></td><td>Reserved for future expansion</td></tr>
</table>

<u>*Commentary*</u>

The RTCA/SC-186/WG-6 (the working group that is drafting a revised ADS-B MASPS, DO-242A) is proposing to replace the 4-bit NUC_P code with a NIC (Navigation Integrity Category) code. If this proposal is accepted by SC-186, then a table of NIC codes from DO-242A will replace Table 2.2.4.1.6 in this MOPS. The range of possible NIC codes would be from 0 to 11.

2.2.4.1.7 "Reserved for NAC_P" Field

The 4-bit field in byte #11, bits 5-8, is reserved for possible use as a NAC_P (Navigation Accuracy Category for Position.)

Note: The following text is in italics to indicate that it is tentative text only, and will not be included in this MOPS if SC-186 does not approve the inclusion of NAC_P as part of SV (State Vector) reports in the next revision of the ADS-B MASPS, DO-242A.

*The NAC_P field (Navigation Accuracy Category for Position) is a 4-bit field (byte #11, bits 5-8) describing the accuracy of the position information conveyed in the Latitude, Longitude fields and, for some NAC_P codes, the geometric altitude field as well. The various NIC codes are defined in **draft** RTCA DO-242A and reproduced in Table 2.2.4.1.7 below.*

Table 2-7. Navigation Accuracy Category Codes.

NAC_P	***95% Horizontal and Vertical Estimated Position Uncertainties (HEPU and VEPU)***	***Comment***
0	*HEPU ³ 10 NM*	*Unknown Accuracy*
1	*HEPU < 10 NM*	*RNP-10 Accuracy*
2	*HEPU < 4 NM*	*RNP-4 Accuracy*
3	*HEPU < 2 NM*	*RNP-2 Accuracy*
4	*HEPU < 1 NM*	*RNP-1 Accuracy*
5	*HEPU < 0.5 NM*	
6	*HEPU < 0.3 NM*	*RNP-0.3 Accuracy*
7	*HEPU < 0.1 NM*	*e.g., GPS-SPS with SA*
8	*HEPU < 0.05 NM*	*e.g., GPS-SPS with SA off*
9	*HEPU < 30 m*	
10	*HEPU < 10 m and VEPU < 15 m*	*e.g., SBAS*
11	*HEPU < 3 m and VEPU < 4 m*	*e.g., WAAS*

2.2.4.1.8 Turn Indicator(TI) [or BAQ (Barometric Altitude Quality)]

The Turn Indicator field is a 2-bit field (byte #12, bits 1-2) that indicates whether or not the aircraft/vehicle is turning. The various Turn Indicator codes are defined in RTCA DO-242 and reproduced in Table 2.2.4.1.8 below.

Table 2.2.4.1.8. Turn Indicator Values

Turn Indicator	Meaning
0	No Turn Information Available
1	Aircraft is NOT Turning at TBD degrees per second or more
2	Aircraft is Turning Right at TBD degrees per second or more
3	Aircraft is Turning Left at TBD degrees per second or more

Note: *Various international and domestic committees responsible for establishing aviation related standards have not agreed upon the thresholds that should be used to determine whether an aircraft is turning. Until such time that firm agreement is reached and standards established, the conventions provided in the following paragraphs should be followed.*

*a. ADS-B transmitting devices shall set the Turn Indicator coding to **"0."***

*b. ADS-B receiving devices shall ignore all Turn Indicator codings other than **"0."***

*c. The ADS-B receiving devices shall set the Turn Indicator coding to **"0"** for all applicable cases until further definition is provided in this document.*

Commentary:

RTCA/SC-186/WG-6, the working group that is drafting DO-242A, the revised ADS-B MASPS, has agreed to remove Turn Indicator from the list of State Vector elements. That working group has also proposed adding a two-bit barometric altitude quality indicator (here denoted BAQ) to the Mode-Status report. If SC-186 agrees to these proposed changes to the ADS-B MASPS, then byte #12, bits 1 and 2, would hold the Barometric Altitude Quality code rather than the Turn Indicator code.

2.2.4.1.9 Air/Ground State

The Air/Ground State field is a 2-bit field (byte #17, bits 7-8) that indicates whether an aircraft is on the ground or airborne. The value of this field determines the encoding of "North Velocity or Ground Speed" and "East Velocity or Track Angle" fields. The possible field values are listed in Table 2-8 below.

Table 2-8. Air/Ground State Values.

Air/Ground State	**Byte #11**		**Meaning**
	Bit 11	Bit 12	
0	0	0	Whether the aircraft is airborne or not is unknown. The horizontal velocity fields hold North Velocity and East Velocity to 0.5 knot resolution.
1	0	1	The aircraft (or surface vehicle) is known to be on the ground. The horizontal velocity fields hold ground speed to 0.25 knot resolution and heading or track angleto 2^{-8} circle (about 1.4 degrees) resolution.
2	1	0	The aircraft is known to be airborne, with a speed of 1023 knots or less. The horizontal velocity fields hold North Velocity and East Velocity to one knot resolution.
3	1	1	The aircraft is known to be airborne, with a speed that may be in excess of 1024 knots. The horizontal velocity fields hold North Velocity and East Velocity to 4-knot resolution.

Commentary:

The working group (RTCA/SC-186/WG-6) that is drafting a revised ADS-B MASPS is currently proposing that heading, rather than track angle, should be required from aircraft that are on the surface and that are above a certain size. (Aircraft below that size could report track angle if they had track angle available. However, the validity flag for the track angle data would be set to "invalid" if the ground speed were so small that the track angle data would be unreliable.)

2.2.4.1.10 V Valid

The V Valid (Velocity Valid) flag is a one-bit field (Byte #12, bit #5) that indicates the validity of the ground speed or north and east velocity in the following fields.

If the Air/Ground State is 0, 2, or 3, the following two fields hold the North and East components of the aircraft's velocity over the ground. In that case, the V Valid bit shall be 1 if both these two fields are known to hold valid data. The V Valid bit shall be zero if either the N Velocity or the E Velocity field is not known to hold valid data.

If the Air/Ground State is 1, the following field holds the ground speed, and the field after that holds either the track angle or the heading. In that case, the V

Valid bit applies only to the ground speed: it shall be 1 if the Ground Speed field holds a valid value, or 0 otherwise.

2.2.4.1.11 North Velocity or Ground Speed

The North Velocity or Ground Speed field is an 11-bit field (byte #12, bit #5 through byte #13, bit #7) for which the meaning is determined by the value of Air/Ground State field.

- If the Air/Ground State is 0, this field holds the N-S component of horizontal velocity, encoded as a signed twos complement binary numeral in which the LSB has a weight of 0.5 knot. The sign is positive for northward velocity, or negative for southward velocity.
- If the Air/Ground State is 1, this field holds the ground speed, encoded as an unsigned binary numeral in which the LSB has a weight of 0.25 knot.
- If the Air/Ground State is 2, this field holds the N-S component of horizontal velocity, encoded as a signed twos complement binary numeral in which the LSB has weight of 1 knot. The sign is positive for northward velocity, or negative for southward velocity.
- If the Air/Ground State is 3, this field holds the N-S component of horizontal velocity, encoded as a signed twos complement binary numeral in which the LSB has weight of 4 knots. The sign is positive for northward velocity, or negative for southward velocity.

2.2.4.1.12 East Velocity or Heading/Track Angle

The East Velocity or Heading/Track Angle field is an 11-bit field (byte #13, bit #8 through byte #15, bit #2) for which the meaning is determined by the value of the Air/Ground State field.

2.2.4.1.12.1 East Velocity

If the Air/Ground State is 0, 2, or 3, the East Velocity or Heading field holds the E-W component of horizontal velocity, encoded as a signed twos complement binary numeral. The sign is positive for eastward velocity, or negative for westward velocity.

- If the Air/Ground State is 0, the LSB has a weight of 0.5 knot.
- If the Air/Ground State is 2, the LSB has a weight of 1 knot.
- If the Air/Ground State is 3, the LSB has a weight of 4 knots.

2.2.4.1.12.2 Heading or Track Angle

If the Air/Ground State is 1, East Velocity or Heading/Track angle field holds a “heading or track angle” flag, a “North reference” flag, a validity flag for the heading or track angle, and the aircraft’s heading or track angle, encoded as an 8-bit angular weight binary numeral.

Table 2.2.4.1.12.2. Heading/Track Angle Encoding.

Byte #	Bit #	Use
14	1	0 = Track Angle, 1 = Heading
	2	0 = True North reference, 1 = Magnetic North reference
	3	1 = Valid heading or track angle, 0 = data invalid
	4	Heading or Track Angle (MSB, 2^{-1} circle = 180°)
	5	
	6	
	7	
	8	
15	1	
	2	
	3	(LSB, 2^{-8} circle = 1.4°)

2.2.4.1.13 Altitude Type

Byte #15, bit #4 holds the “altitude type” flag. This bit shall be 0 if the primary altitude is pressure altitude, or 1 if the primary altitude is geometric altitude. The secondary altitude field (which is to be found in long ADS-B messages) will hold the other kind of altitude: geometric altitude if the Altitude Type code is 0, or pressure altitude if the Altitude Type code is 1.

Table 2.2.4.1.13. Altitude Type Codes.

Alt. Type	Primary Altitude	Secondary Altitude
0	Pressure Altitude	Geometric Altitude
1	Geometric Altitude	Pressure Altitude

If NUC_P is in the range from 0 to 7 and valid barometric pressure altitude is available, the transmitting ADS-B system shall set the altitude type flag to 0, indicating that the primary altitude is barometric pressure altitude.

If NUC_P is 8 or 9, or valid barometric pressure altitude is not available, the transmitting ADS-B system shall set the primary altitude type flag to 1, indicating that the primary altitude is geometric altitude.

2.2.4.1.14 Primary Altitude

The Primary Altitude field is a 12-bit field (byte #15, bit #5 through byte #16, bit #8) that encodes whichever altitude (pressure altitude or geometric altitude) is specified by the Altitude Type field (section 2.2.4.1.13) as the primary altitude. The field is encoded as (altitude + 1000 feet) in 25-foot units. This permits altitudes in the range from -1000 feet to more than +100 000 feet to be encoded in this 12-bit field. The “all ones” coding is reserved to mean “altitude is unavailable.”

Table 2.2.4.1.14. Primary Altitude Encoding.

0000 0000 0000	-1000 feet
0000 0000 0001	-975 feet
…	
0000 0010 0111	-25 feet
0000 0010 1000	0 feet
0000 0010 1001	+25 feet
…	
1111 1111 1110	+101350 feet
1111 1111 1111	Invalid or unknown altitude

<u>Commentary</u>:

The DO-242 MASPS requires (in §2.1.2.2.1.2) that altitude be provided with a range from –1,000 feet up to +100,000 feet. The MASPS also requires (in Table 3-4) that the standard deviation of the ADS-B contribution to vertical position error be 30 feet or less. With 25-foot resolution, the quantization error due to truncation or rounding will have a standard deviation of

$$s_{vp} = \frac{25\,ft}{\sqrt{12}} = 7.22\,ft$$

Thus, coding the altitude field in this way meets both those requirements of the MASPS.

2.2.4.1.15 Primary Altitude Rate

The Primary Altitude Rate is encoded in a 10 bit field (byte #17, bit #1 through byte #18, bit #2). If the Altitude Type field is 0, the Primary Altitude Rate field shall hold the rate of change of barometric pressure altitude. If the Altitude Type field is 1, the Primary Altitude Rate field shall hold the rate of change of geometric altitude (height above the WGS-84 ellipsoid.)

The altitude rate is encoded as a signed twos complement binary numeral in which LSB has a weight of 64 feet/minute. However, there are three exceptions:

- The most negative possible value (binary 10 0000 0000) is reserved to indicate that altitude rate is invalid or not available.
- The most negative of the remaining values (binary 10 0000 0001) is reserved to indicate that the altitude is decreasing at a rate of 32 672 feet per minute or more.
- The most positive of the values (binary 01 1111 1111) is reserved to indicate that the altitude is increasing at a rate of 32 672 feet per minute or more.

Table 2.2.4.1.15 indicates the altitude rate encoding in more detail.

Table 2.2.4.1.15. Primary Altitude Rate Encoding.

Encoding (Binary)	Meaning
10 0000 0000	Altitude Rate is invalid or unknown.
10 0000 0001	Descending at 32,672 feet per minute or more
10 0000 0010	-32,640 feet/minute
…	…
11 1111 1101	1192 feet/minute
11 1111 1110	-128 feet/minute
11 1111 1111	-64 feet/minute
00 0000 0000	0 feet/minute
00 0000 0001	+64 feet/minute
00 0000 0010	+128 feet/minute
00 0000 0011	+192 feet/minute
…	…
01 1111 1110	+32,640 feet/minute
01 1111 1111	Ascending at 32,672 feet/minute or more

Commentary:

The ADS-B MASPS, RTCA DO-242, requires (in §2.1.2.2.2.2) that altitude rate be reported with a range of plus or minus 32,000 feet per minute. The MASPS also requires (in Table 3-4) the 1-sigma ADS-B contribution to altitude rate error should be1 foot per second or less. With a resolution of 64 feet/minute, this encoding of altitude rate has a 1-sigma ADS-B contribution (due to rounding error) of

$$s_{vv} = \frac{(64/60)\,ft/\sec}{\sqrt{12}} = 0.31\,ft/\sec$$

Thus this encoding of altitude rate meets both those requirements of the MASPS.

2.2.4.1.16 NUC_R [or NAC_V]

The NUC_R (Navigation Uncertainty Category for Rate) is a 4-bit field (byte #18, bits #3 to 36) that indicates the accuracy of the velocity information. The values of this field are defined in RTCA DO-242 and reproduced in Table 2.2.4.1.16 below.

Commentary:

The working group (RTCA/SC-186/WG-6) that is drafting a revised ADS-B MAPS (to be named DO-242A), has proposed to rename the NUC_R field as NAC_V (Navigation Accuracy Category for Velocity).

Table 2.2.4.1.16. NUC_R Codes

NAC_V	Horizontal Velocity Uncertainty (95%)	Vertical Velocity Uncertainty (95%)
0	Unknown	Unknown
1	< 10 m/s	< 50 feet/second
2	< 3 m/s	< 15 feet/second
3	< 1 m/s	< 5 feet/second
4	< 0.3 m/s	< 1.5 feet/second

Note 1: When an internal navigation system is used as the source of velocity information, error in velocity with respect to WGS-84 is reflected in the NAC_V code.

Note 2: When any component of velocity is not available, the value of NAC_V will apply to the other components that are supplied.

2.2.4.1.17 T Valid (UTC Coupled) Flag

The T Valid (UTC Coupled) flag is a 1-bit field (byte #18, bit #7) that indicates whether the message transmission was synchronized with the start of a valid MSO (message start opportunity).

- The transmitting station (aircraft, ground vehicle, or TIS-B transmitter) shall set T Valid = 1 only if the first bit of 36-bit synchronization sequence that precedes the message payload was transmitted within TBD microseconds of the nominal MSO selected for the time of transmission of the message.
- Otherwise, the transmitting station shall set T Valid = 0.

2.2.4.1.18 Reserved Bit

Byte #18, bit #0 is reserved for future definition, and shall be 0.

2.2.4.2 Type 1 Long ADS-B Message Payload Format and Encoding

Table 2.2.4.2-A shows the overall format of the payload in the Type 1 Long ADS-B Message. The format of the first 18 bytes in the message is identical to that in the Basic ADS-B Message, described in section 2.2.4.1. . Bytes and bits are transmitted in "big-endian" order; that is, the most significant byte is transmitted first, and within each byte, the most significant bit, bit #1, is transmitted first. Table 2.2.4.2-B lists the fields in Table 2.2.4.1-A and the subsection where those fields are described.

Table 2.2.4.2-A. Format of Long Type 1 ADS-B Payload.

Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	
1-18	**(See Table 2.2.4.1-A)**								
19	(MSB)	**Participant Category Code and Flight ID (Call Sign) Characters#1 and #2**							**MS and SV Data**
20		(Base-40 encoding)						(LSB)	
21	(MSB)	**Flight ID (Call Sign) Characters #3, #4, and #5**							
22		(Base-40 Encoding)						(LSB)	
23	(MSB)	**Flight ID (Call Sign) Characters #6, #7, and #8**							
24		(Base 40 Encoding)						(LSB)	
25	(MSB)	**Transmission Epoch (6 LSBs of 12-bit MSO #)**				(LSB)	***Res, for SIL***		
26	(MSB)	**Capability Class (CC)**							
27		**Codes**						(LSB)	
28	(MSB)	**Operational Mode**							
29		**(OM) Codes**						(LSB)	
30	**Emergency/Priority Status**			**MOPS Version**			(MSB)		
31	**Secondary Altitude**								
32		(LSB)	**Hdg Valid**	**Hdg. Ref.**	(MSB)	**Heading**			**OC-ARV Data**
33					(LSB)	**TAS/IAS**	(MSB)		
34					**Airspeed**			(LSB)	

<u>Table 2.2.4.2-B</u>: Type 1 ADS-B Long Message Fields.

Field Name	# of Bits	Section Reference	
Participant Category Code and Flight ID	48	2.2.4.2.1	MS and SV Data
Transmission Epoch	6	2.2.4.2.2	
Res. for Surveillance Integrity Level (SIL)	2	2.2.4.2.3	
Capability Class (CC) Codes	16	2.2.4.2.4	
Operational Mode (OM) Codes	16	2.2.4.2.5	
Emergency/Priority Status	3	2.2.4.2.6	
MOPS Version Number	3	2.2.4.2.7	
Secondary Altitude	12	2.2.4.2.8	
Heading Valid	1	2.2.4.2.9	OC-ARV Data
Heading Reference	1	2.2.4.2.9	
Heading	9	2.2.4.2.9	
Airspeed Reference	1	2.2.4.2.9	
Airspeed	10	2.2.4.2.9	

2.2.4.2.1 Participant Category Code and Call Sign

The participant category code and call sign are encoded as nine base-40 digits, packed, three digits at a time, into three 16-bit fields in the Type 1 Long ADS-B message. The encoding of the participant category and the flight ID characters as base-40 digits are specified in subsection 2.2.4.2.1.1 and 2.2.4.2.1.2 below. The packing of these base-40 digits into the message is described in subsection 2.2.4.2.1.3.

2.2.4.2.1.1 Participant Category Code

The participant category code is a number in the range from 0 to 31, which is regarded as a base-40 digit in the range from 0 to 31.

Table 2-12. ADS-B Emitter Category Codes

Base-40 Digit (Decimal)	Emitter Category	Base-40 Digit (Decimal)	Participant Category
0	No ADS-B emitter category information	16	(Reserved)
1	Light (< 15 500 lbs)	17	Surface Vehicle - Emergency Vehicle
2	Small (15 500 to 75 000 lbs)	18	Surface Vehicle – Service Vehicle
3	Large (75 000 to 300 000 lbs)	19	Fixed Ground or Tethered Obstruction
4	High Vortex Large (aircraft such as B-757)	20	(Reserved)
5	Heavy (> 300,000 lbs)	21	(Reserved)
6	High Performance (> 5 g acceleration and > 400 knots)	22	(Reserved)
7	Rotorcraft	23	(Reserved)
8	(Reserved)	24	(Reserved)
9	Glider or Sailplane	25	(Reserved)
10	Lighter-than-Air	26	(Reserved)
11	Parachutist / Skydiver	27	(Reserved)
12	Ultralight / Hang-glider / Paraglider	28	(Reserved)
13	(Reserved)	29	(Reserved)
14	Unmanned Aerial Vehicle	30	(Reserved)
15	Space / Trans-atmospheric vehicle	31	(Reserved)

2.2.4.2.1.2 Flight ID (Call Sign) Characters

The Flight ID consists of eight characters, which must be decimal digits, uppercase letters, or the space character. The 37 possible different characters are represented as base-40 digits in the range from 0 to 36. The first two characters of the Flight ID are packed, together with the participant category code, into bytes 19 and 20 of the Type 1 Long ADS-B message. The next three characters are likewise packed into bytes 21 and 22, and the last three characters into bytes 23 and 24.

Table 2.2.4.2.1.2: shows the base-40 character coding used for the Flight ID characters.

Table 2.2.4.2.1.2: Base-40 Character Code for Flight ID.

Base-40 Digit (Decimal)	Character	Base-40 Digit (Decimal)	Character
0	0	20	K
1	1	21	L
2	2	22	M
3	3	23	N
4	4	24	O
5	5	25	P
6	6	26	Q
7	7	27	R
8	8	28	S
9	9	29	T
10	A	30	U
11	B	31	V
12	C	32	W
13	D	33	X
14	E	34	Y
15	F	35	Z
16	G	36	SPACE
17	H	37	(unused)
18	I	38	(unused)
19	J	39	(unused)

2.2.4.2.1.3 Packing Method for Participant Category and Flight ID.

Let C be the base-40 digit representing the participant category code, and let A_1, A_2, A_3, A_4, A_5, A_6, A_7, A_8 be the base 40 digits representing the eight characters of the Flight ID. Then bytes 19 and 20 of the Type 1 Long ADS-B Message shall hold the binary numeral for the number,

$$C\times 40^2 + A_1\times 40 + A_2.$$

Likewise, bytes 21 and 22 of the Type 1 Long ADS-B Message shall hold the binary numeral for the number,

$$A_3\times 40^2 + A_4\times 40 + A_5$$

and bytes 23 and 24 of the Type 1 Long ADS-B Message shall hold the binary numeral for the number,

$$A_6\times 40^2 + A_7\times 40 + A_8.$$

2.2.4.2.2 Transmission Epoch

There are 4000 possible MSOs (Message Start Opportunities) in each one-second UAT frame, so the scheduled time of transmission of an ADS-B message may be encoded as a 12-bit binary numeral giving an MSO number in the range from 0 to 3999. In the Type 1 Long ADS-B message, the 6 LSBs of that 12-bit MSO number are encoded into byte #25, bits #1 through #6.

The validity bit for the Transmission Epoch field is the “T Valid” flag (byte #18, bit #5, described in section 2.2.4.1.17 above).

2.2.4.2.3 Reserved for Surveillance Integrity Level (SIL)

<u>Commentary</u>:

The Surveillance Integrity Level is a 2-bit code that is proposed by the DO-242A MASPS working group, RTCA/SC-186/WG-6, to indicate the integrity level associated with the proposed NIC (Navigation Integrity Category). The SIL code defines the probability of the containment radius selected by the NIC code being exceeded, without the possiblity of the containment radius being exceeded being detected at the transmitting A/V.

Space is reserved in this draft MOPS text for the SIL code. Whether the SIL code is actually incorporated in the published MOPS will depend on whether or not the draft DO-242A revised MASPS is accepted by SC-186. The "Reserved for SIL" field is a 2-bit filed (byte #25, bits #7 and #8) that is reserved for use a Surveillance Integrity Level Code.

SIL is encoded in a 2-bit field (byte #18, bits 7-8). It indicates the level of confidence that may be placed on the position being within the integrity radius that is encoded in the NIC field. The various integrity levels are defined in <u>Table 2.2.4.2.3</u> below.

<u>Table 2.2.4.2.3</u>. Navigation Integrity Level Codes.

Integrity Level	**Probability of Exceeding Integrity Radius Without An Integrity Alarm**	**Comment**
0	10^{-3} per flight hour or per operation	
1	10^{-5} per flight hour or per operation	
2	10^{-7} per flight hour or per operation	
3	10^{-9} per flight hour or per operation	

2.2.4.2.4 Capability Class (CC) Codes

The capability class codes are transmitted as a 16-bit field (bytes #26 and #27, bits #1 to #8) in which the bits are typically Boolean flags indicating whether or not the transmitting aircraft has a certain capability. Table 2.2.4.2.4 lists the capability class code bits. Each bit is 1 if the associated capability is present, 0 otherwise.

Table 2-14. Capability Class (CC) Codes.

Byte #	Bit #	Capability
26	1	CDTI based traffic display capability
	2	TCAS/ACAS installed and operational
	3	***Service Level of transmitting aircraft (range 0 to 3)***
	4	(Reserved)
	5	***Can send OC-ARV (On-Condition Air Referenced Velocity report elements***
	6	***Can send Target Altitude***(Reserved)
	7	***Trajectory Change Point Information (TCP, TCP+1, TCP+2, TCP+3)***
	8	(Reserved)
27	1	(Reserved)
	2	(Reserved)
	3	(Reserved)
	4	(Reserved)
	5	(Reserved)
	6	(Reserved)
	7	(Reserved)
	8	(Reserved)

Commentary:

*The capabilities indicate with **bold underlined italic text** in the above table are those proposed in the current draft DO-242A text being considered by WG-6. Whether or those specific capability class codes are included in this MOPS will depend on whether or not they are included in the final DO-242A text that is approved by SC-186.*

2.2.4.2.5 Operational Mode (OM) Codes

The Operational Mode (OM) codes are transmitted as a 16-bit field (bytes #28 and #29, bits #1 to #8). . Table 2.2.4.2.5 lists the operational mode bits. Each bit is 1 if the associated mode is active, 0 otherwise.

Table 2.2.4.2.5: Operational Mode (OM) Codes.

Byte #	Bit #	Capability	Section Reference
28	1	***Sending OC-ARV report elements (Heading and Airspeed)***	
	2	***Sending Target Altitude)***	
	3	***Sending Target Heading or Track Angle***	
	4	***ACAS/TCAS Resolution Advisory Active***	
	5	***Sending TCP information***	
	6	***Sending TCP+1 information***	
	7	***Sending TCP+2 information***	
	8	***Sending TCP+3 information***	
29	1	(Reserved)	
	2	(Reserved)	
	3	(Reserved)	
	4	(Reserved)	
	5	(Reserved)	
	6	(Reserved)	
	7	(Reserved)	
	8	(Reserved)	

Commentary:

*The operational mode codes indicates with **bold underlined italic text** in the above table are those proposed in the current draft DO-242A text being considered by WG-6. Whether or those specific operational mode codes are included in this MOPS will depend on whether or not they are included in the final DO-242A text that is approved by SC-186.*

2.2.4.2.6 Emergency/Priority Status

Emergency/Priority Status is transmitted in a 4-bit field (byte #30, bits #1 to #4). The possible Emergency/Priority Status codes are defined in Table 2.2.4.2.6.

Table 2.2.4.2.6: Emergency/Priority Status Code.

Code	Meaning
0	No Emergency Reported
1	General Emergency
2	Lifeguard / Medical Emergency
3	Minimum Fuel
4	No Communications
5	Unlawful Interference
6	(Reserved for future definition)
7	(Reserved for future definition)

2.2.4.2.7 MOPS Version Number

The MOPS Version Number is a three-bit field (Byte #30, bits #4 to #6) which shall be ZERO.

Note 1: *Non-zero values of the MOPS Version Number field are reserved to provide a way for future UAT equipment to indicate that they comply with later versions of this MOPS.*

Note 2: *It is very important that future versions of this MOPS should leave undisturbed the encoding of all message fields for which the encoding is specified in this initial version of the MOPS. Otherwise, "version 0" equipment (equipment that conforms to the initial version of this MOPS) will not be able to interpret correctly the messages coming from equipment that conforms to later versions of the MOPS.*

2.2.4.2.8 Secondary Altitude

The Secondary Altitude field is a 12-bit field (byte #30, bit #7 through byte #32, bit #2) that contains either the aircraft's height above the WGS-84 ellipsoid or its barometric pressure altitude.

- If the Altitude Type field (section 2.2.4.1.13) is 0, the Secondary Altitude is the geometric altitude: the height above the WGS-84 ellipsoid.
- If the Altitude Type field is 1, the Secondary Altitude is the pressure altitude.

The encoding of Secondary Altitude is the same as for Primary Altitude. (See section 2.2.4.1.14.). The field is encoded as (altitude + 1000 feet) in 25-foot units. This permits geometric altitudes in the range from -1000 feet to more than +100 000 feet to be encoded in this 12-bit field. The "all ones" coding is reserved to mean "geometric altitude is unavailable or invalid."

```
0 0 0 0 0 0 0 0 0 0 0 0 = -1000 feet
0 0 0 0 0 0 0 0 0 0 0 1 =  -975 feet
. . .
0 0 0 0 0 0 0 0 0 1 1 1 =   -25 feet
0 0 0 0 0 0 1 0 1 0 0 0 =     0 feet
0 0 0 0 0 0 1 0 1 0 0 1 =   +25 feet
. . .
1 1 1 1 1 1 1 1 1 1 1 0 = +101350 feet
1 1 1 1 1 1 1 1 1 1 1 1 =   “invalid secondary altitude” or
                            “secondary altitude unknown”
```

2.2.4.2.9 Air Referenced Velocity: Heading Fields

Eleven bits (byte #32, bit #3 through byte #33, bit #5) are reserved for heading component of the On Condition – Air Referenced Velocity (OC – ARV) report. Table 2.2.4.2.9 shows the usage of these 11 bits.

Commentary:

The proposed DO-242A “Revision A” to the ADS-B MASPS would not require the Airspeed and Heading SV elements to be reported by all ADS-B participants all of the time. Instead, it is proposed to move those elements from the SV report to a new On Condition – Air Referenced Velocity (OC-ARV) that would not be required from all ADS-B participants, and would not be required at the same update rate as the SV report. This draft text anticipates that proposed change.

Table 2.2.4.2.9: Air Referenced Velocity – Heading Fields.

Byte #	Bit #	Use	
31	1	**Heading. Valid Flag**	0 = Invalid, 1 = Valid
	2	**Heading Reference Direction**	0 = True, 1 = Magnetic
	3	**Heading**	(MSB, weight = 180° = 2^{-1} circles)
	4		(2^{-2} circles)
	5		(2^{-3} circles)
	6		(2^{-4} circles)
	7		(2^{-5} circles)
	8		(2^{-6} circles)
32	1		(2^{-7} circles)
	2		(2^{-8} circles)
	2		(LSB, weight 2^{-9} circles = 0.70 degrees)

2.2.4.2.10 Air Referenced Velocity: Airspeed fields

Eleven bits (byte #32, bit #6 through byte # 34, bit #8) are reserved for the Airspeed components of the On Condition – Air Referenced Velocity (OC-ARV) report. Table 2.2.4.2.10 shows the bit allocation for the Airspeed elements.

Commentary:

The proposed DO-242A "Revision A" to the ADS-B MASPS would not require the Airspeed and Heading SV elements to be reported by all ADS-B participants all of the time. Instead, it is proposed to move those elements from the SV report to a new On Condition – Air Referenced Velocity (OC-ARV) that would not be required from all ADS-B participants, and would not be required at the same update rate as the SV report. This draft text anticipates that proposed change.

Table 2.2.4.2.10: Airspeed Bit Allocation.

Byte #	Bit #	Use	
32	4	**Airspeed Reference**	0 = TAS, 1 = IAS
	5	**Airspeed**	(MSB, weight = 512 knots / 2048 knots)
	6		(256 knots / 1024 knots)
	7		(128 knots / 512 knots)
	8		(64 knots / 256 knots)
33	1		(32 knots / 128 knots)
	2		(16 knots / 64 knots)
	3		(8 knots / 32 knots)
	4		(4 knots / 16 knots)
	5		(2 knots / 8 knots)
	6		(LSB, weight = 1 knot or 4 knots)

The weight of the bits in the Airspeed field depends on the value in the Air/Ground State field (section 2.2.4.1.9). If the Air/Ground state value is 3, the weight of the LSB in the TAS field shall be 4 knots, and values in the range from 0 to 4088 knots can be encoded. Otherwise (i.e., if the Air/Ground state value is 0, 1, or 2) the weight of the LSB in the TAS field shall be 1 knot, and values in the range from 0 to 1022 knots can be encoded.

The "all ones" value (binary 11 1111 1111) shall indicate an invalid or unknown airspeed value.

2.2.4.3 Type 2 Long ADS-B Payload Format and Encoding

Table 2.2.4.3-A shows the overall format of the payload in the Type 2 Long ADS-B Message. Bytes and bits are transmitted in “big-endian” order; that is, the most significant byte is transmitted first, and within each byte, the most significant bit, bit #1, is transmitted first.

The formats of the first 29 bytes, and bits #1 to #6 of byte #30, are identical to the corresponding parts of the Type 1 Long Message Format (section 2.2.4.2).

Table 2.2.4.3-A. Format of Long Type 2 ADS-B Payload.

Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
1-18	**(See Table 2.2.4.1-A)**							
19	(MSB)	**Participant Category Code and Flight ID (Call Sign) Characters#1 and #2**						
20		(Base-40 encoding)						(LSB)
21	(MSB)	**Flight ID (Call Sign) Characters #3, #4, and #5**						
22		(Base-40 Encoding)						(LSB)
23	(MSB)	**Flight ID (Call Sign) Characters #6, #7, and #8**						
24		(Base 40 Encoding)						(LSB)
25	(MSB)	**Transmission Epoch (6 LSBs of 12-bit MSO #)**				(LSB)	***Res, for SIL***	
26	(MSB)	**Capability Class (CC)**						
27		**Codes**						(LSB)
28	(MSB)	**Operational Mode**						
29		**(OM) Codes**						(LSB)
30	**Emergency/Priority Status**			**MOPS Version Number**			(MSB)	
31	**Secondary Altitude**							
32		(LSB)	***Reserved for Aircraft Size Code***					
33	**(Elements of another OC report, TBD.)**							
34								

Table 2.2.4.3-B. Long Type 2 ADS-B Message Payload Fields.

Field Name	# of Bits	Section Reference	
Participant Category Code and Flight ID	48	2.2.4.2.1	**SV and MS Data**
Transmission Epoch	6	2.2.4.2.2	
Res. for Surveillance Integrity Level (SIL)	2	2.2.4.2.3	
Capability Class (CC) Codes	16	2.2.4.2.4	
Operational Mode (OM) Codes	16	2.2.4.2.5	
Emergency/Priority Status	3	2.2.4.2.6	
MOPS Version Number	3	2.2.4.2.7	
Secondary Altitude	10	2.2.4.3.8	
Reserved for Aircraft Size Code	4	2.2.4.3.9	
Reserved for future definition	20		

2.2.4.3.1 Participant Category Code and Flight ID

Bytes #19 to #24 of the Long Type 2 ADS-B Message format are identical to the corresponding bytes in the Long Type 1 Message format. See section 2.2.4.2.1.1 for details.

2.2.4.3.2 Transmission Epoch

The Transmission Epoch is encoded in byte #25, bits #1 to #6. See section 2.2.4.2.2 for details.

2.2.4.3.3 Surveillance Integrity Level (SIL)

Byte #25, bits #7 and #8, are reserved for the Surveillance Integrity Level (SIL). See section 2.2.4.2.3 for details.

2.2.4.3.4 Capability Class (CC) Codes

Bytes #26 and #27 of the Long Type 2 ADS-B Message format are identical to the corresponding bytes in the Long Type 1 Message format. See section 2.2.4.2.4 for details.

2.2.4.3.5 Operational Mode (OM) Codes

Bytes #28 and #29 the Long Type 2 ADS-B Message format are identical to the corresponding bytes in the Long Type 1 Message format. See section 2.2.4.2.5 for details.

2.2.4.3.6 Emergency/Priority Status

As in the Long Type 1 Message format, Byte #30, bits #1 to #3, of the Long Type 2 Message Format hold the Emergency/Priority Status code. See section 2.2.4.2.6 for details.

2.2.4.3.7 MOPS Version Number

As in the Long Type 1 Message format, byte #30, bits #4 to #6, of the Long Type Type 2 Message Format hold the MOPS Version Number. See section 2.2.4.2.7 for details.

2.2.4.3.8 Secondary Altitude

As in the Long Type 1 Message format, byte #30, bits #7 and #8, and byte #31, bits #1 to #8, hold the Secondary Altitude element of the SV report. See section 2.2.4.2.8 for details.

2.2.4.3.9 Reserved for Aircraft Size Code

A four-bit field (byte #32, bits #3 to #6) is reserved for possible use as an Aircraft Size Code field.

<u>Note</u>: *The working group (RTCA/SC-186/WG-6) that is preparing a draft revised ADS-B MOPS (to be designate DO-242A) has identified "Aircraft Size Code" as a report element that may be required for certain surface applications. Only aircraft above a certain size would be required to transmit the Aircraft Size Code, and only when those aircraft are on the surface.*

2.2.4.3.10 Reserved Bits in Long Type 2 Message Format

The final bits of the Long Type 2 Message format are reserved for future definition.

<u>Commentary</u>:

These bits might well be used for elements of some other kind of On Condition report: "selected altitude," "target altitude,"and "target heading or track angle" are possibilities. [These are elements of a proposed new On Condition – Target State Report (OC-TSR) that is being proposed for inclusion in the next revision (DO-242A) of the MASPS.]

2.2.4.4 Long Type 3 ADS-B Message (Original format for TCP and TCP+1)

The Long Type 3 ADS-B Message Format is used to convey trajectory change information (TCP, TCP+1).

<u>Commentary</u>:

> *The only fields in the Long Type 3 ADS-B Message fort are those TCP and TCP+1 report elements that were defined in the <u>original</u> version, DO-242, of the ADS-B MASPS.. Any more elaborate TCP report elements that may be proposed for future versions of the MASPS would be encoded in the Long Type 4 ADS-B Message format.*

Table 2.2.4.4-A shows the overall format of the payload in the Type 3 Long ADS-B Message. Bytes and bits are transmitted in "big-endian" order, that is, the most significant byte is transmitted first, and within each byte, the most significant bit, bit #1, is transmitted first.

The formats of the first 29 bytes, and of bits #1 to #6 of byte #30, are identical to the corresponding parts of the Type 1 and Type 3 Long Message formats.

<u>Table 2.2.4.4-A</u>. Format of Long Type 3 ADS-B (TCP, TCP+1) Message.

Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	
1-18				**(See Table 2.2.4.1-A)**					
19		**TCP Validity Flags**		(MSB)					**TCP Information**
20					**TCP Latitude**				**TCP Information**
21					(LSB)				**TCP Information**
22					**TCP Longitude**				**TCP Information**
23							(LSB)	(MSB)	**TCP Information**
24					**TCP Altitude**				**TCP Information**
25	(LSB)	(MSB)			**TCP Time-To-Go**				**TCP Information**
26			(LSB)			(Reserved for future definition)			**TCP Information**
27		**TCP+1 Validity Flags**		(MSB)					**TCP+1 Information**
28	(MSB)				**TCP+1 Latitude**				**TCP+1 Information**
29					(LSB)	(MSB)			**TCP+1 Information**
30					**TCP+1 Longitude**				**TCP+1 Information**
31							(LSB)	(MSB)	**TCP+1 Information**
32					**TCP+1 Altitude**				**TCP+1 Information**
33	(LSB)	(MSB)			**TCP+1 Time-To-Go**				**TCP+1 Information**
34			(LSB)			(Reserved for future definition)			**TCP+1 Information**

<u>Table 2.2.4.4-B:</u> Long Type 3 ADS-B Message (TCP, TCP+1) Fields.

<table>
<tr><th>Field Name</th><th># of Bits</th><th>Section Reference</th><th></th></tr>
<tr><td>TCP Validity Flags</td><td>3</td><td>2.2.4.4.1</td><td rowspan="6">TCP Data</td></tr>
<tr><td>TCP Latitude</td><td>18</td><td>2.2.4.4.2</td></tr>
<tr><td>TCP Longitude</td><td>18</td><td>2.2.4.4.3</td></tr>
<tr><td>TCP Altitude</td><td>10</td><td>2.2.4.4.4</td></tr>
<tr><td>TCP Time-To-Go</td><td>10</td><td>2.2.4.4.5</td></tr>
<tr><td>TCP reserved bits</td><td>5</td><td>2.2.4.4.6</td></tr>
<tr><td>TCP+1 Validity Flags</td><td>3</td><td>2.2.4.4.1</td><td rowspan="6">TCP+1 Data</td></tr>
<tr><td>TCP+1 Latitude</td><td>18</td><td>2.2.4.4.2</td></tr>
<tr><td>TCP+1 Longitude</td><td>18</td><td>2.2.4.4.3</td></tr>
<tr><td>TCP+1 Altitude</td><td>10</td><td>2.2.4.4.4</td></tr>
<tr><td>TCP+1 Time-To-Go</td><td>10</td><td>2.2.4.4.5</td></tr>
<tr><td>TCP+1 reserved bits</td><td>5</td><td>2.2.4.4.6</td></tr>
</table>

2.2.4.4.1 TCP or TCP+1 Validity Flags

Bits #1 to #3 in byte #19 are validity flags that indicate whether or not the following TCP data fields contain valid data. Likewise, bits #1 to #3 in byte #27 indicate whether or not the following TCP+1 data fields. Each validity flag shall be 1 if the corresponding data field has valid data, or 0 otherwise.

Table 2.2.4.4.1: Validity Flags in Type 0 TCP Message Format.

<table>
<tr><th>Byte #</th><th>Bit #</th><th>Usage</th></tr>
<tr><td rowspan="3">19
or
27</td><td>1</td><td>TCP (TCP+1) Horizontal Position Valid</td></tr>
<tr><td>1</td><td>TCP (TCP+1) Altitude Valid</td></tr>
<tr><td>8</td><td>TCP (TCP+1) Time-To-Go Valid</td></tr>
</table>

2.2.4.4.2 TCP or TCP+1 Latitude

The TCP or TCP+1 Latitude is encoded as an 18-bit angular weighted binary numeral.

2.2.4.4.3 TCP or TCP+1 Longitude

The TCP or TCP+1 Longitude is encoded as an 18-bit angular weighted binary numeral.

2.2.4.4.4 TCP or TCP+1 Altitude

The TCP or TCP+1 Altitude, plus 1000 feet, is encoded in a 10-bit field. The LSB of the field shall have a weight of 25 feet.

2.2.4.4.5 TCP or TCP+1 Time-To-Go

The TCP or TCP+1 Time-To-Go (TTG) is encoded in a 10-bit field, in one-second units. Times to Go in the range from 0 s to 17 m 2 s (1022 s) are represented by binary numerals in the range from 0 to 1022. The “all ones” coding (the binary numeral for 1023) shall be used to indicate a Time To Go of more than 1022 seconds.

2.2.4.4.6 TCP or TCP+1 Reserved Bits

The last five bits (bits #4 to #8) of bytes #26 and 34 in the Long Type 3 Message format are reserved for future definition, and shall be zero.

2.2.4.5 Long Type 4 ADS-B Message

The Type 4 Long ADS-B Message format is intended for use with new, more elaborate, TCP, TCP+1, TCP+2, and TCP+3 reports. Table 2.2.4.5-A shows the bit allocation for Type 4 Long ADS-B Messages.

Commentary:

The details of the new On Condition report formats for trajectory change points (OC-TCP, OC-TCP+1, OC-TCP+2, OC-TCP+3, etc.) are not yet defined. It is expected that such more elaborate report formats, including new, additional, report fields, might be defined in future versions of the DO-242 MASPS. The purpose of the Long Type 4 ADS-B Message format is to provide a generalized TCP+N message structure that can be refined in future versions of this MOPS.

Table 2.2.4.5-A: Type 4 TCP Message Format.

Byte #	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
1-18	**(See Table 2.2.4.1-A)**							
19	**Message Subtype**		**TCP Number, N**			**TCP+N Validity Flags**		
20	(MSB)							
21				**TCP+N Latitude**				
22		(LSB)	(MSB)					
23				**TCP+N Longitude**				
24				(LSB)	(MSB)			
25				**TCP+N Altitude**		(LSB)	(MSB)	
26				**TCP+N Time-To-Go**				(LSB)
27-34	***Reserved for Future Definitions***							

Table 2.2.4.5-B: Type 4 Long ADS-B Message Fields.

Field Name	# of Bits	Section Reference
Message Subtype	2	2.2.4.5.1
TCP Number, N	3	2.2.4.5.2
TCP+N Validity Flags	3	2.2.4.5.3
TCP+N Latitude	18	2.2.4.5.4
TCP+N Longitude	18	2.2.4.5.5
TCP+N Altitude	10	2.2.4.5.6
TCP+N Time-To-Go	10	2.2.4.5.7
Variable Information		2.2.4.5.8

2.2.4.5.1 Long Type 4 Message Subtype

The most significant bits of byte #19 in the Type 4 Long ADS-Message format are reserved to indicate the type of TCP being conveyed in the remainder (bytes #20 to #34) of the message. Table 2.2.4.5.1 specifies the encoding of this field.

Table 2.2.4.5.1: TCP Type Encoding

TCP Type	Meaning
0	Minimum TCP information, just what was specified in the initial version of the DO-242 ADS-B MASPS.
1	Reserved for future definition
2	Reserved for future definition
3	Reserved for future definition

Commentary:

Additional TCP types may be added, depending on WG-6's progress in revising the ADS-B MASPS.

2.2.4.5.2 TCP Number, N

Three bits (byte #19, bits #3 to #5) are reserved for the TCP sequence number ("N" in the expression "TCP+N"). The current TCP, for which the TCP number is zero, is the trajectory change point towards which the aircraft is currently being controlled. "TCP+1" refers to the next trajectory change point after that.

Note 1: *The three-bit field allows for the possibility of as many as eight TCP: TCP, TCP+1, TCP+2, …, TCP+7. However, as this MOPS is being written, only a maximum of 4 TCPs are anticipated as requirements.*

Note 2: *If TCP Type = 0 (section 2.2.4.5.1), the only valid TCP numbers are 0 and 1. This is to provide backwards compatibility with TCPs as defined in the initial, DO-242, version of the ADS-B MASPS.*

2.2.4.5.3 TCP+N Validity Flags

Three bits (byte #19, bits #6 through #8) are allocated for validity flags for the TCP+N Latitude and Longitude, TCP+N Altitude, and TCP+N Time To Go fields in the Type 4 Long ADS-B Message format. Table 2.2.4.5.3 shows the usage of these bits, which is similar to the usage of the corresponding bits in the Type 3 Long ADS-B Message.

Table 2.2.4.4.1: Validity Flags in Type 4 Long ADS-B Message Format.

Byte #	Bit #	Usage
19	6	TCP+ N Horizontal Position Valid
	7	TCP+N Altitude Valid
	8	TCP+N Time-To-Go Valid

2.2.4.5.4 TCP+N Latitude

Eighteen bits (byte #20, bit #1, through byte #22, bit #2) are allocated for TCP+N Latitude. The encoding of this 18-bit field shall be as specified in section 2.2.4.4.2 for the corresponding field in the Type 3 Long ADS-B Message.

2.2.4.5.5 TCP+N Longitude

Eighteen bits (byte #22, bit #3, through byte #25, bit #4) are allocated for TCP+N Longitude. The encoding of this 18-bit field shall be as specified in section 2.2.4.4.3 for the corresponding field in the Type 3 Long ADS-B Message.

2.2.4.5.6 TCP+N Altitude

Ten bits (byte #24, bit 5, through byte #25, bit #6) are allocated for TCP+N Altitude. The encoding of this 10-bit field shall be as specified in section 2.2.4.4.4 for the corresponding field in the Type 3 Long ADS-B Message.

2.2.4.5.7 TCP+N Time To Go

Ten bits (byte #25, bit # 7, through byte #26, bit #8) are allocated for TCP+N Time To Go. The encoding of these bytes shall be as specified in section 2.2.4.4.5 for the corresponding field in the Type 3 Long ADS-B Message.

2.2.4.5.8 Variable Information

The remainder of the Type 4 Long ADS-B Message format (bytes #27 to #34) is variable information, with the format depending on the Message Subtype.

<< End of draft text for Section 2.2.4 of the UAT MOPS.>>